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On the velocity of transfer by the He II film

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The transfer effect in the helium film has been studied fairly thoroughly by a number of authors (1-11). As a result of a large number of experiments it has been established that the speed of transfer between two levels of liquid helium in vessels connected by the film is determined by the temperature, and it could be concluded that at constant temperature the velocity of transfer remains practically constant until complete equality of the levels is obtained.

However, there has recently appeared a number of papers (12-13) in which it was shown that in certain conditions the velocity of transfer at constant temperature depends on the distance (H) between the higher level and the edge of the container. Moreover it appeared that the speed of transfer may have values an order of magnitude greater than shown earlier (especially (9)). Such results were obtained using vessels of special form (capillaries ending up in a sphere (12)), and for careful protection of the vessel from radiation (13). It later turned out (14-15) that these anomalous properties of transfer are observed in such cases where the walls of the vessel are covered by a thin layer of solid air, which could have happened in filling the apparatus by means of condensation of insufficiently pure helium. It seemed that this showed, as it were, that the large values of velocity and its dependence on H might be attributed to the contaminated surface of the vessel.

However, in spite of the full rehabilitation of the earlier established properties of transfer, there was evidently a need for new experiments in the determination of the speed of transfer. The point is that even in the experiments carried out particularly carefully (5-8), a large velocity of transfer was obtained when the level of liquid helium was near the edge of the vessel, followed by

a slight diminution of velocity as the level diminished; these did not receive complete explanation. On the other hand, the measured velocity up to now had to be corrected for normal evaporation. Also the ampule was inside the dewar, and the temperature had to be maintained by the pumping of helium, which might have led to certain errors. Since we are concerned with a matter important for the theory of He II, i.e. existence of a critical velocity of transfer, there was naturally the desire to set up new experiments in conditions eliminating all possibilities of confusion.

In the present article we communicate some results of experiments carried out in such conditions.

As usual, the velocity of transfer was determined by observations of the change of level of helium in a glass ampule, but in contrast to previous experiments, the ampule was not now simply placed in the dewar containing liquid helium, but in a glass vessel with copper ends; this was surrounded by a copper screen with observation slits through which the levels could be observed, and was filled with liquid helium from the dewar through a valve. The ground joint situated in the upper part of the apparatus permitted the ampule to be placed at the desired height. This arrangement protected the walls of the ampule from possible contamination by solid air and eliminated the errors connected with normal evaporation; it also reduced to a minimum the influx of heat radiation into the ampule.

After establishment of the required temperature in the dewar, the apparatus was filled with liquid helium and the glass ampule lowered, filled, and raised up again. By means of a cathetometer the dependence on time of the level height in the ampule was taken up to the complete equalization of the levels in the ampule and the apparatus; this gave the possibility of determing the velocity of outflow of the helium via the film. In other cases, the ampule was lowered so that the boiling level [illegible] the helium level in the

vessel, and the speed of flow of helium into the ampule then observed.

The experiments were carried out with three different glass ampules. One of them was cylindrical and had a diameter 2.54 mm; the second had the same diameter but a copper base to improve the heat exchange; the third had a cylindrical part of the same diameter, and went even lower down into a sphere of diameter 20 mm. The last of these had the aim of increasing the amount of liquid in the ampule. The rate of change of level in the ampule was studied for outflow and inflow. Typical results are shown in fig.1, in which is shown the dependence on time t of the distance H of the level of the helium from the edge of the ampule. For convenience of looking at the corrections they are displaced along the axis of abscissae. Curve (a) refers to the case of continuous flow from the glass ampule filled to the brim with liquid helium. It is clearly seen that the velocity of change of level varies continuously with time, achieving a constant value right up to full equalization of the levels. Detailed investigation showed that the process of transfer is determined by the height H, and it is not dependent on the difference of levels apart from the region where the He level is close to the edge, when the velocity of transfer is determined by the level. The values of velocity of transfer far from the brim of the ampule are close to those established earlier (9). For obtaining the curve (b), the ampule was raised partially ((b1) and after (b2)). Such a stepwise lifting of the ampule leads to the same results as in the case of continuous flow, and curve (b) is parallel to curve (a).

A different picture is observed in the case where the ampule was filled with liquid helium (but not to the brim) without lowering the ampulle right into the helium, but through the film. For this purpose the ampule was lowered to the desired depth in the helium, and after equalization of the levels was lifted again. The velocity of flow observed in this case was appreciably less (curve c) for equal values of

H than for the case of outflow of the ampule filled by submersion. Curves d,e,f, were obtained in similar ways for the ampules with a copper base; the ampule with a sphere leads to the same result. Curve (d) is for continuous flow, (e) for stepwise flow, and (f) for flow after partial filling of the ampule through the film. This time, reduction of the velocity was observed both in the cases (e) and (f).

The inflow takes place in such conditions that H remains constant throughout the experiment and the velocity of flow also remains constant. This velocity was determined both for H increasing and for H diminishing. Comparison of the velocities of inflow and outflow for one and the same H shows that the velocity of inflow was somewhat smaller. For comparison with the results of other authors, experiments were also carried out with the glass ampule in the usual way, the ampule being simply put in the helium dewar. In this case, all these peculiarities were hardly observable, and it is probable that in such experimental conditions they could not have been discovered earlier.

Although there is as yet no possibility of completely explaining all the observed regularities, it can be concluded that the effect of transfer through the film is appreciably more complicated than appeared up to now, and that in all probability thermal effects arising in the transfer have an appreciable influence on the processes of transfer. In support of this point of view, there is the diminution of velocity of outflow before equalization of the levels; this is possibly connected with the occurrence of the thermo-mechanical effect. These considerations are supported by the existence of a small velocity of outflow if first the ampule was filled by helium through the film, and finally also by the differences of the effect of transfer for a glass ampule and for an ampule with a copper base, or a sphere. It can be supposed that in the process of transfer a temperature difference appears between the helium in the ampule and the helium in the apparatus,

which causes the recondensation of helium. The possibility is also not excluded that the process of transfer is correlated with the pre-history of formation of the film. The peculiarities of the transfer effect indicated show up for great uniformity of temperature. In our experiments the temperature variation in the dewar did not exceed 3×10^{-4} °K, while in the inner vessel the variations were still smaller.

Thus it seems possible to explain the contradictions between the results obtained by the various authors. Using previous methods which did not smooth out the pressures over the film, the dependence of velocity on H was either not observed at all, or only weakly shown ((7) and (15-17)). The method used by us always leads to a clearly expressed dependence of the velocity of transfer on H (18-19) and to the other peculiarities of the transfer effect indicated in the present article.

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REFERENCES

1. A. Kikoin and B. Lazarev, Nature 141, 912, 1938.
2. " " " " " ibid 142, 289, 1938.
3. " " " " " Fiz. Zap. A.N., U.S.R.S. 9, 1, 1940.
4. P.G. Strelkov, J. Exp. Theor. Phys., USSR, 10, 743, 1940.
5. " " " Dissertation, Leningrad, 1938.
6. J. Daunt and K. Mendelssoh, Nature, 141, 911 (1938).
7. " " " " " ibid., 142, 475, 1938.
8. " " " " " Proc. Roy. Soc. A, 170, 423, 1939.
9. " " " " " ibid., A 170, 439, 1939.
10. " " " " Nature, 143, 719, 1939.
11. B. Rollin and F. Simon, Physica, 6, 219, 1939.
12. K. Atkins, Nature, 161, 925, 1948.
13. B. de Haas and van den Berg, Rev. Mod. Phys., 21, 524, 1949.
14. R. Bowers and K. Mendelssohn, Nature, 163, 870, 1949.
15. " " " " " Proc. Phys. Soc. A. 63, 1318, 1950.

16. J. Brown and K. Mendelssohn, ibid., A, 63, 1312, 1950.

17. K. Mendelssohn and G. White, ibid., A, 63, 1328, 1950.

18. K. Atkins, Proc. Roy. Soc., 203, 119, 1950.

19. K. Atkins, ibid., 203, 240, 1950.

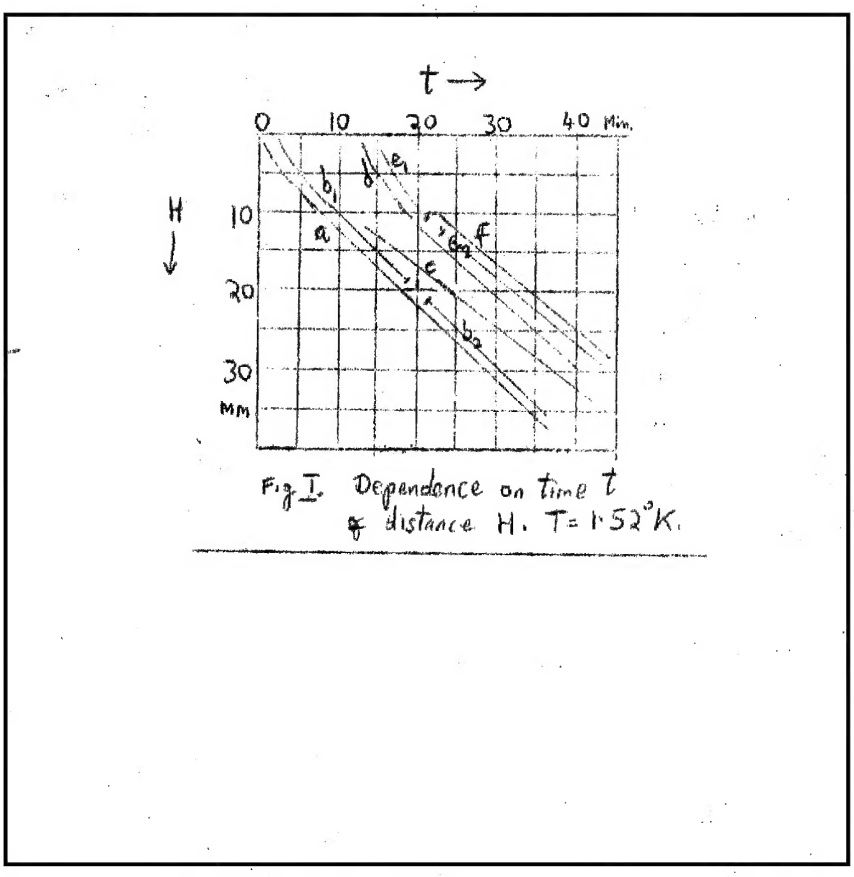

Fig I. Dependance on time t of distance H. $T = 1{\cdot}52°K$.